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(54) POLYMERES ABSORBANT L'EAU DOTES DE COMPOSES A ESPACES VIDES UN PROCEDE POUR LEUR  
PRODUCTION ET LEUR UTILISATION  
(54) WATER-ABSORBING POLYMERS HAVING INTERSTITIAL COMPOUNDS, A PROCESS FOR THEIR  
PRODUCTION, AND THEIR USE

(57) The invention relates to water and aqueous fluid-absorbing mediums based on polymers which are water-swellable, but not water-soluble wherein silicium-rich zeolites are bonded ionically and/or on the basis of mechanical inclusions.

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(54) Title: WATER-ABSORBING POLYMERS HAVING INTERSTITIAL COMPOUNDS, A PROCESS FOR THEIR  
PRODUCTION, AND THEIR USE

(57) Abrégé/Abstract:

The invention relates to water and aqueous fluid-absorbing mediums based on polymers which are water-swellable, but not water-soluble wherein silicium-rich zeolites are bonded ionically and/or on the basis of mechanical inclusions.

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**Abstract:**

The invention relates to absorbents for water and aqueous liquids, which absorbents are based on water-swelling, yet water-insoluble polymers wherein zeolites high in silicon have been incorporated ionically and/or as a result of mechanical inclusion.

**Water-absorbing Polymers Having Interstitial Compounds,  
a Process for Their Production, and Their Use**

The invention relates to absorbents for water and aqueous liquids, which absorbents are based on water-swelling, yet water-insoluble polymers wherein zeolites high in silicon have been incorporated ionically and/or as a result of mechanical inclusion.

Commercially available superabsorbing polymers essentially are crosslinked polyacrylic acids, crosslinked starch-acrylic acid graft copolymers, crosslinked hydrolyzed starch/acrylonitrile graft copolymers, crosslinked poly-(maleic anhydride-co-isobutylene), or mixtures of various of the above-mentioned crosslinked polymers, wherein the carboxylic groups have been subjected to partial neutralization with sodium and/or potassium ions. Such polymers find use e.g. in hygiene articles capable of absorbing body fluids such as urine or menstrual fluid or in absorbent pads in packagings for foodstuffs where they absorb large amounts of aqueous liquids and body fluids such as urine or blood with swelling and formation of hydrogels. Furthermore, the absorbed amount of liquid must be retained under a pressure typical of use. During the further technical development of superabsorbing polymers, the pattern of requirements to be met by these products has changed significantly over the years.

To date, the development of superabsorbers has been forced particularly with respect to the amount of absorbed liquid and pressure stability. Such crosslinked polymer products based on monomers containing acid groups are obtained by using one or more primary crosslinkers and/or one or more secondary crosslinkers and exhibit a combination of proper-

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ties, namely, high retention, high absorption under pressure, low solubles, rapid absorption of liquid, and high permeability in the swollen state, which has not been achieved so far. When used in hygiene articles, these crosslinked polymer products have the advantage that secreted fluids, once absorbed by the polymer product, can no longer contact the skin. Thus, skin lesions such as diaper dermatitis can largely be avoided. Such comfort can even be increased by absorbing malodorous compounds.

According to Römpf Chemie Lexikon, the content of urine components and thus, of malodorous compounds, is subject to physiological fluctuations; also, particular substances are secreted at concentrations varying within a daily period, so that more precise data on the urine composition invariably are related to the so-called 24 hour urine which, in a healthy adult, contains e.g. urea (average 20 g), uric acid (0.5 g), creatinine (1.2 g), ammonia (0.5 g), amino acids (2 g), proteins (60 mg), reducing substances (0.5 g, about 70 mg of which are D-glucose or urine sugar), citric acid (0.5 g) and other organic acids, as well as certain vitamins (C, B<sub>12</sub> etc.). The following inorganic ions are present: Na<sup>+</sup> (5.9 g), K<sup>+</sup> (2.7 g), NH<sub>4</sub><sup>+</sup> (0.8 g), Ca<sup>2+</sup> (0.5 g), Mg<sup>2+</sup> (0.4 g); Cl<sup>-</sup> (8.9 g), PO<sub>4</sub><sup>3-</sup> (4.1 g), SO<sub>4</sub><sup>-2</sup> (2.4 g). The dry content is between 50 and 72 g. *Inter alia*, alkylfurans, ketones, lactones, pyrrole, allyl isothiocyanate, and dimethyl sulfone have been recognized as volatile components of urine. Most of the volatile components are molecules having a molar mass below about 1000 g/mol and a high vapor pressure.

Volatile components of urine have also been investigated by, *inter alia*, A. Zlatkis et al. (Anal. Chem. Vol. 45, 763ff.). It is also well-known that consumption of asparagus results in an increase of the concentration of organic sulfur-containing compounds in human urine (R.H. Waring, Xenobiotika, Vol. 17, 1363ff.). In patients who are subject to

specific diets and/or ingest specific medications, or in elderly individuals with decreasing kidney function, the urine may include malodorous substances. Patients suffering from urine incontinence have an increased secretion of ureases which convert the urea contained in urine, thereby liberating toxic ammonia. Also, a pathological change is well-known which is referred to as fish smell syndrome. It results from an increased secretion of quaternary ammonium compounds. Also, menstrual fluid may acquire an unpleasant odor. Among other things, this odor is produced by microbial degradation of secreted proteins. Typical odorous substances in menstrual fluid and the smells produced by degradation of blood components are not substantially different from the smell of components occurring in urine. In this case as well, low molecular weight compounds having a molar weight of less than 1000 g/mol are involved. Predominantly, nitrogen-containing heterocycles such as pyrrole, pyridine and derivatives thereof may be mentioned. Furthermore, those smells liberated by foodstuffs may be mentioned, e.g. the smell of fish (amines).

The odorous components in vaginal secretions and menstruation fluid have been investigated by G. Huggins and G. Preti (Clinical Obstetrics and Gynecology, Vol. 24, No. 2, June 1981, 355-377), where low molecular weight substances having a molar weight below 500 g/mol have been found. Fatty acids (e.g. butyric acid, isovaleric acid) and some aromatic compounds such as pyridine, indole and thymine may be emphasized, which particularly contribute to unpleasant odors. The amount of volatile fatty acids varies over the time period of the menstrual cycle (Human Vaginal Secretions: Volatile Fatty Acid Content, Richard P. Michael, R. W. Bonsall, Patricia Warner, Science, 27 December 1974, 1217-1219). Amines have not been found in vaginal secretions and menstruation fluid. This is because the pH value of the secretion in a healthy female patient is in the acidic range where, at most, ammonium salts are present which are non-volatile. It is only in pathological conditions where proteins increasingly can be

converted to amines by bacterial degradation, which may enter the vapor space in case of a simultaneous increase of the pH value.

Previous approaches of achieving an odor reduction in incontinence products and Ladies' hygiene products are based on reducing the concentration of free ammonia. Basically, there are two approaches to this end: preventing additional production of ammonia from urea degradation by suitable urease inhibitors (A. Norberg et al., Gerontology, 1984, 30, 261ff.), or by protonating free ammonia and binding thereof in the form of a carboxylate ammonium salt. This method is disadvantageous in that essentially, merely ammonia and other nitrogen-containing components can be controlled. Malodorous compounds lacking basic groups, e.g. thiols, are still capable of entering the vapor space.

It is well-known to those skilled in the art that zeolites have high adsorptive properties.

Zeolites mostly are synthetic compounds comprised of silicon oxide, aluminum oxide and a number of metal ions. Their composition is  $M_2O_z \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$  wherein M = uni- or multivalent metal, H, ammonium, etc., z = valency, x = from 1.8 to about 12, and y = from 0 to about 8. Structurally, zeolites are comprised of  $SiO_4$  and  $AlO_4$  tetrahedrons linked via oxygen bridges, thereby forming a channel system of equally structured and equally large interconnected cavities. Zeolites are named according to their pore openings, e.g. zeolite A (4.2 Å), zeolite X (7.4 Å). When heated, most zeolites release their water continuously, without altering their crystal structure. In this way, they are capable of accommodating other compounds, acting as e.g. catalysts or ion exchangers. Furthermore, zeolites exhibit a screening effect by incorporating molecules having a smaller cross-section than the pore openings in the lattice channel system. Larger molecules are excluded. Cations are required to

balance the negative charge of the  $\text{AlO}_4$  tetrahedrons in the aluminosilicate skeleton.

Inter alia, the synthesis of zeolites has been described extensively in: *Zeolite Synthesis*, ACS Symposium Series 398, Eds. M.L. Ocelli and H.E. Robson (1989) pp. 2-7. The synthesis of hydrophobic zeolites having a silicon dioxide/aluminum oxide ratio in the skeleton of >100, high hydrothermal stability and resistance to aqueous alkaline solutions is disclosed in the patent application DE 195 32 500 A1. The zeolites have a grain size of markedly less than 150  $\mu\text{m}$ .

The patent document US 4,795,482 teaches the use of hydrophobic zeolites to suppress and avoid organic odors. The reduction of odors was measured using headspace gas chromatography.

It is well-known from the patent applications WO 91/12029 and WO 91/12031 that the hydrophobic zeolites described in US 4,795,482 or produced in a similar way can be used in combination with superabsorbers, where the zeolite is "essentially" bound to the superabsorber. The composites thus obtained are used in hygiene articles such as diapers or liners. The mixture is produced by mixing the superabsorber with the zeolite in dry condition. Water is subsequently added, where aggregation of the particles has been observed (WO 91/12031). Following a drying step, the mixture can be incorporated in hygiene products. In the patent application WO 91/12029, the zeolite is dispersed in water together with a binder and coated onto the superabsorber in a coating process where at least 20% zeolite, relative to the superabsorber, is to be used.

Both of these procedures are disadvantageous in that binding of the zeolite material to the polymer is exceedingly weak, and separation and demixing of superabsorber and zeo-

lite may occur even at low mechanical stress on the composite. Such mechanical stress occurs e.g. when conveying a superabsorber and/or an absorbent article including superabsorbing polymers. In addition to demixing, problems of handling exceedingly fine particles also arise. Also, when subjecting the superabsorber to a secondary treatment with aqueous dispersions possibly containing binders, damage to the superabsorber structure and the associated swelling properties must be expected. The high percentage of non-swellable zeolite material in the superabsorber composite represents an additional limitation to the pattern of properties.

It is well-known from the patent applications EP 0,811,387 A1 and EP 0,811,390 A1 that zeolites having a silicon dioxide/aluminum oxide ratio of from 1 to 5 can be used as odor absorbents in liners. The products produced according to the above document were subjected to a practical test, and the used products were rated in an olfactory test panel with test persons. The dry mixtures described in the above-mentioned patent applications readily undergo demixing. In addition, the amounts of required zeolite as taught in the above patent applications are exceedingly high, having a disadvantageous effect on the wearing comfort of hygiene articles.

The present invention therefore is based on the object of providing a polymer capable of absorbing water and aqueous liquids, which polymer has a substance by means of which malodorous organic compounds such as occurring e.g. in urine or other fluids secreted from the body are bound, and wherein

- malodorous materials released into the vapor space during use are markedly reduced;
- a virtually uniform distribution of deodorant substance in the absorbent is present;
- demixing in the condition prior to and during use is avoided as much as possible;

- the absorbent has good retention properties and swelling properties under pressure; and
- the deodorant modification is ensured using amounts of deodorant substance as low as possible.

The present invention is also based on the object of providing a process for producing said deodorant absorbent wherein

- in particular, problems with mixing of dry substances differing substantially in their particle size, such as granulates and powders, are avoided;
- no dust is formed; and
- aggregation of the particles during production is avoided.

According to the invention, said object is accomplished by means of an absorbent polymer constituted of crosslinked, monoethylenically unsaturated, partially neutralized monomers bearing acid groups, which polymer has zeolites high in silicon bound or incorporated in an ionic or mechanical fashion.

In the meaning of the invention, "high in silicon" means that the silicon dioxide/aluminum oxide ratio is  $>10$ , preferably  $>20$ , more preferably  $>50$ , and even more preferably  $>100$ . A silicon dioxide/aluminum oxide ratio of  $>500$  is particularly preferred.

In the meaning of the invention, "crosslinked" means that the polymer is crosslinked and/or surface-crosslinked.

The zeolites to be used according to the invention are dealuminized, hydrophobic (organophilic) zeolite variants having a silicon dioxide/aluminum oxide ratio in their skeletons of  $>10$ , preferably  $>20$ , more preferably  $>50$ , with  $>100$  being particularly preferred. A ratio of  $>500$  is most preferred. The amount to be used is 0.01-10 wt.-%, preferably

0.1-5 wt.-%, and more preferably 0.70-3 wt.-%, relative to the total amount of absorbent. For example, such zeolites are traded by Degussa AG under the trade name Flavith® or by UOP under the designation of Abscents®. Flavith® is characterized in more detail in the KC-CZ 42-1-05-1098 T&D product data sheet. Said product data sheet is hereby incorporated by reference and thus represents part of the disclosure.

Various processes are possible for polymerizing the polymer of the invention optionally having superabsorbent properties, e.g. bulk polymerization, solution polymerization, spray polymerization, inverse emulsion polymerization, and inverse suspension polymerization. Preferably, a solution polymerization is performed using water as solvent. The solution polymerization may be conducted in a continuous or batchwise fashion. The patent literature includes a broad spectrum of possible variations with respect to concentration conditions, temperatures, type and amount of initiators and of secondary catalysts. Typical processes have been described in the following patent specifications: US 4,286,082; DE 27 06 135, US 4,076,663, DE 35 03 458, DE 40 20 780, DE 42 44 548, DE 43 23 001, DE 43 33 056, DE 44 18 818. These disclosures are hereby incorporated by reference and thus represent part of the disclosure.

The unsaturated acid group-containing monomers to be used according to the invention are, e.g. acrylic acid, methacrylic acid, crotonic acid, isocrotonic acid, maleic acid, fumaric acid, itaconic acid, vinylacetic acid, vinylsulfonic acid, methallylsulfonic acid, 2-acrylamido-2-methyl-1-propanesulfonic acid, as well as the alkali and/or ammonium salts thereof. It is preferred to use acrylic acid and its alkali and/or ammonium salts and mixtures thereof. Furthermore, it is also possible to use monomers being hydrolyzed to form acid groups as late as subsequent to the polymerization as is possible e.g. with nitrile groups.

In order to modify the polymer properties, up to 30 wt.-% of other comonomers soluble in the aqueous polymerization batch, such as acrylamide, methacrylamide, acrylonitrile, (meth)allyl alcohol ethoxylates, and mono(meth)acrylic acid esters of alcohols or ethoxylates can optionally be used.

Minor amounts of crosslinking monomers having more than one reactive group in their molecules are copolymerized together with the above-mentioned monomers, thereby forming partially crosslinked polymer products which are no longer soluble in water but merely swellable. Bi- or multifunctional monomers, e.g. amides such as methylenebisacryl- or -methacrylamide, or ethylenebisacrylamide may be mentioned as crosslinking monomers, and also, allyl compounds such as allyl (meth)acrylate, alkoxylated allyl (meth)acrylate reacted preferably with from 1 to 30 mol of ethylene oxide, triallyl cyanurate, maleic acid diallyl ester, polyallyl esters, tetraallyloxyethane, triallylamine, tetraallylethylenediamine, allyl esters of phosphoric acid or phosphorous acid, and also, crosslinkable monomers such as N-methylol compounds of unsaturated amides like methacrylamide or acrylamide and the ethers derived therefrom, as well as esters of polyols and alkoxylated polyols, such as diacrylates or triacrylates, e.g. butanediol or ethylene glycol diacrylate, polyglycol di(meth)acrylates, trimethylolpropane triacrylate, di- and triacrylate esters of trimethylolpropane preferably oxyalkylated (ethoxylated) with 1 to 30 mol alkylene oxide, acrylate and methacrylate esters of glycerol and pentaerythritol, and of glycerol and pentaerythritol preferably oxyethylated with 1 to 30 mol ethylene oxide. It is preferred to use triallylamine, acrylates of polyhydric alcohols or alkoxylates thereof, and methallyl alcohol acrylates or alkoxylates thereof. The ratio of crosslinking monomers is from 0.01 to 3.0 wt.-%, preferably from 0.05 to 2.0 wt.-%, and more preferably from 0.05 to 1.5 wt.-%, relative to the total monomers.

The acidic monomers preferably are subjected to neutralization. The neutralization can be performed in various ways. On the one hand, according to the teaching of US 4,654,039, the polymerization may be conducted directly with the acidic monomers, with neutralization being effected subsequently in the polymer gel. This patent specification is hereby incorporated by reference and thus represents part of the disclosure. On the other hand and preferably, the acidic monomer components are neutralized to 20-95%, preferably 50-80% prior to polymerization, in which case they are present as sodium and/or potassium and/or ammonium salts at the time polymerization is begun. It is preferred to use those bases for neutralization which do not adversely affect the subsequent polymerization. It is preferred to use sodium or potassium hydroxide solution and/or ammonia, with sodium hydroxide solution being particularly preferred; addition of sodium carbonate, potassium carbonate or sodium bicarbonate may have an additional positive effect as taught in US 5,314,420 and US 5,154,713. Before initiating the polymerization in this adiabatic solution polymerization, the partially neutralized monomer solution is cooled to a temperature of below 30°C, preferably below 20°C. These patent specifications are hereby incorporated by reference and thus represent part of the disclosure. In the other processes mentioned, other temperatures are also well-known and conventional according to the state of the art.

The polymer products of the invention may contain water-soluble polymers as a basis for grafting in amounts up to 40 wt.-%. *Inter alia*, these include partially or completely saponified polyvinyl alcohols, starch or starch derivatives, cellulose or cellulose derivatives, polyacrylic acids, polyglycols, or mixtures thereof. The molecular weights of the polymers added as basis for grafting must be adapted to the circumstances of the polymerization conditions. In the event of an aqueous solution polymerization, for example, it may be necessary for viscosity reasons to employ low or medi-

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um molecular weight polymers only, whereas this factor plays a minor role in a suspension polymerization.

In addition to polymers obtained by crosslinking polymerization of partially neutralized acrylic acid, those are preferably used which additionally contain components of graft-polymerized starch, or of polyvinyl alcohol.

The polymerization process of the invention can be initiated by various conditions, e.g. by irradiating with radioactive, electromagnetic or ultraviolet radiation, or by a redox reaction of two compounds, e.g. sodium hydrogen sulfite with potassium persulfate, or ascorbic acid with hydrogen peroxide. The thermally induced decomposition of a so-called free-radical initiator such as azobisisobutyronitrile, sodium peroxodisulfate, t-butyl hydroperoxide, or dibenzoyl peroxide may also be used as initiation of polymerization. Furthermore, a combination of some of the above-mentioned methods is possible.

In principle, the polymer products are produced according to two methods:

According to the first method, the partially neutralized acrylic acid is converted to a gel by means of free-radical polymerization in aqueous solution and in the presence of crosslinkers and optional polymer additives, which gel is subsequently crushed and dried until a powdered, flowable state is reached, milled, and screened to the desired particle size. The solution polymerization may be conducted in a continuous or batchwise fashion. The patent literature includes a broad spectrum of possible variations with respect to concentration conditions, temperatures, type and amount of initiators, as well as a variety of secondary crosslinking options. Typical processes have been described in the following patent specifications: US 4,076,663; US 4,286,082; DE 27 06 135, DE 35 03 458, DE 35 44 770, DE 40 20 780, DE

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42 44 548, DE 43 23 001, DE 43 33 056, DE 44 18 818. These documents are hereby incorporated by reference and thus represent part of the disclosure.

The inverse suspension and emulsion polymerization process may also be used to produce the polymer products. In these processes, an aqueous, partially neutralized solution of acrylic acid is dispersed in a hydrophobic organic solvent using protective colloids and/or emulsifiers, and the polymerization is initiated using free-radical initiators. The crosslinkers are either dissolved in the monomer solution and metered together with same or added separately and optionally subsequently. The optionally present polymeric grafting bases are added via the monomer solution or by directly placing in the oil phase. Subsequently, the water is removed azeotropically from the mixture, and the polymer product is filtrated and optionally crushed and dried until a powdered, flowable state is reached, milled, and screened to the desired particle size.

Using the process of subsequent surface crosslinking, the polymer products according to the invention can be improved in their pattern of properties, particularly in their absorption of liquid under pressure, so that the well-known phenomenon of "gel blocking" is suppressed, where slightly swelled polymer particles adhere to each other, thereby impeding further absorption of liquid and distribution of liquid e.g. within the diaper. In this secondary crosslinking, the carboxyl groups of the polymer molecules are crosslinked at the surface of the superabsorber particles at elevated temperature using crosslinking agents. Methods of secondary crosslinking have been described in several written specifications, e.g. in DE 40 20 780, EP 317,106 and WO 94/9043.

According to the invention, all those secondary crosslinking agents known to a person skilled in the art from US 5,314,420, page 8, lines 3-45, may be used advantageously

in combination with a primary crosslinker or a combination of crosslinkers. The above-mentioned documents are hereby incorporated by reference and thus represent part of the disclosure. As a rule, these compounds contain at least two functional groups capable of reacting with carboxylic acid or carboxyl groups. Alcohol, amine, aldehyde, and carbonate groups are preferred and also, crosslinker molecules having multiple different functions are employed. Preferably, polyols, polyamines, polyaminoalcohols, polyepoxides, and alkylene carbonates are used. In particular, one of the following secondary crosslinking agents is used: ethylene glycol, diethylene glycol, triethylene glycol, polyethylene glycol, glycerol, polyglycerol, propylene glycol, diethanolamine, triethanolamine, polypropylene glycol, block copolymers of ethylene oxide and propylene oxide, sorbitan fatty acid esters, ethoxylated sorbitan fatty acid esters, trimethylolpropane, ethoxylated trimethylolpropane, pentaerythritol, ethoxylated pentaerythritol, polyvinyl alcohol, sorbitol, ethylene carbonate, propylene carbonate. It is particularly preferred to use polyols and ethylene carbonate as secondary crosslinking agents. The secondary crosslinking agent is employed in an amount of from 0.01 to 30 wt.-%, preferably 0.1-10 wt.-%, relative to the polymer to be subjected to secondary crosslinking.

Prior to secondary crosslinking, the polymer preferably is dried, milled, screened for the respective grain fraction favorable in application-technical terms, and subsequently fed into the secondary crosslinking reaction. In some cases, however, it has proven beneficial to add the secondary crosslinkers at an early stage prior to drying the polymer gel or prior to crushing the partially or predominantly dried polymer. Secondary crosslinking to be performed according to the invention has been described in US 4,666,983 and DE 40 20 780. These documents are hereby incorporated by reference and thus represent part of the disclosure. Advantageously, the secondary crosslinker frequently is added in the

form of a solution in water, organic solvents or mixtures thereof, particularly in those cases where low amounts of secondary crosslinking agent are used. Suitable mixing apparatus for applying the secondary crosslinking agent are, e.g., Patterson-Kelley mixers, DRAIS turbulence mixers, Lödige mixers, Ruberg mixers, screw mixers, pan mixers, and fluid-bed mixers, as well as continuously operated vertical mixers wherein the powder is mixed at a rapid frequency using rotating knives (Schugi mixer). Once the secondary crosslinker has been mixed with the pre-crosslinked polymer, heating to temperatures of from 60 to 250°C, preferably from 135 to 200°C, and more preferably from 150 to 185°C is effected in order to perform the secondary crosslinking reaction. The time period for additional heating is limited by that point where the desired pattern of properties of the polymer product is destroyed as a result of heat damage.

Depending on the type of use, various screening fractions are employed for processing the polymer products, e.g. between 100 and 1000  $\mu\text{m}$  and preferably between 150 and 850  $\mu\text{m}$  for diapers. In general, this grain fraction is produced by milling and screening prior to and/or subsequent to secondary crosslinking.

In the polymer product of the invention for absorbing water or aqueous liquids, the zeolite component can be extracted by the liquid to be absorbed to only a lesser extent, or, in the dry state, undergo demixing to only a lesser extent. Surprisingly, it has been found that the zeolites not even partly lose their ability of absorbing odors as a result of the intimate linkage with the crosslinked polymer bearing acid groups. In this way, the vapor space concentration of malodorous substances is effectively reduced. The deodorant substances are applied from a suspension, for example. In this way, any dust problems during manufacturing are avoided. It has also been found that the zeolites neither lose their ability of absorb-

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ing odors when applied from an aqueous suspension. Furthermore, it has been found that the other quality criteria relevant for polymers having superabsorbent properties, namely, high retention and absorption against pressure, are not adversely affected by applying zeolite.

The polymer product of the invention is excellently suited for incorporating active substances, and when used, these active substances can optionally be released in a controlled fashion. By incorporation in the polymer products of the invention, the stability of sensitive active substances is markedly improved.

The present invention is also directed to a process for producing the absorbent polymer products of the invention.

According to the process of the invention, the absorbent polymer product of the invention is produced by:

- free-radical polymerization of an aqueous solution of ethylenically unsaturated, optionally partially neutralized monomers bearing acid groups and crosslinking monomers according to the process of solution or suspension polymerization to form a hydrogel;
- optional isolation;
- crushing, followed by drying, milling;
- optional screening; and
- surface crosslinking;

wherein the zeolite high in silicon is added to the polymer product during its surface crosslinking at the latest.

Preferably, the zeolite is added in suspension.

In the meaning of the invention, "high in silicon" means that the silicon dioxide/aluminum oxide ratio is >10, preferably >20, more preferably >50, and even more preferably

>100. A silicon dioxide/aluminum oxide ratio of >500 is particularly preferred.

The zeolite is employed in suspension. A preferred liquid phase is water, but mixtures of water and organic solvents are also used.

According to the invention, the addition of zeolite can be effected at various process stages in the production of the powdered polymer product, as illustrated below. By applying the zeolite from an aqueous suspension onto the polymer product prior to or during one of the process steps in the production thereof, particularly effective binding between the odor-absorbing component and the polymer product is achieved.

In a preferred embodiment of the process according to the invention, the zeolite is added directly to the aqueous monomer solution prior to polymerization. In case the absorbent is produced by suspension polymerization, it is also possible to precharge all or part of the zeolite in the oil phase and meter the monomer solution thereto. Where only part of the zeolite is precharged, the remainder is to be added via the monomer solution.

In another preferred embodiment of the process according to the invention, the zeolite is applied onto the crushed polymer gel in the form of a suspension in water or an organic solvent or mixtures thereof.

Furthermore, the polymer gel preferably is subjected to at least partial drying and the zeolite subsequently is applied onto the powder in the form of a suspension in water or an organic solvent or mixtures thereof. The resulting product can be dried directly as such and subjected to surface crosslinking.

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In another preferred embodiment of the process according to the invention, the zeolite is employed in the processing step of secondary crosslinking. Suitable mixing apparatus for applying the secondary crosslinking agent are e.g. Patterson-Kelley mixers, DRAIS turbulence mixers, Lödige mixers, Ruberg mixers, screw mixers, pan mixers, and fluid-bed mixers, as well as continuously operated vertical mixers wherein the powder is mixed at a rapid frequency using rotating knives (Schugi mixer).

It is also preferred to incorporate the zeolite at various stages of the production process of the absorbent polymers so as to optimize the effect of the zeolite and utilize synergies.

According to another process of the invention, the absorbent polymer product of the invention is produced by:

- free-radical polymerization of an aqueous solution of ethylenically unsaturated, optionally partially neutralized monomers bearing acid groups and crosslinking monomers according to the process of solution or suspension polymerization to form a hydrogel;
- optional isolation;
- crushing, followed by drying, milling;
- optional screening;

wherein the zeolite high in silicon is added to the polymer product at a stage where the water content thereof is at least 10 wt.-%.

Preferably, the addition of zeolite high in silicon is effected in suspension.

According to the invention, the water content must not be reduced below 10 wt.-% before the zeolite high in silicon is added.

Preferably, the water content must not be reduced below 30 wt.-%, more preferably not below 50 wt.-%, and even more preferably not below 65 wt.-% before the zeolite high in silicon is added.

The addition of the zeolite to the polymer product preferably is effected using a suspension.

Using the process according to the invention, absorbent polymers are obtained wherein the zeolite is incorporated in the synthetic polymer in such a way that the cannot be removed completely from the polymer product even after mechanical stressing e.g. in a ball mill at 95 rpm for 6 minutes. In the process of the invention, less than 80% and generally 40-60% of the total amount of zeolite applied onto the polymer product is removed after such stressing.

Compared to powdered absorbents including no zeolite, the polymer products of the invention exhibit improved absorption of malodorous compounds.

The polymer products find use e.g. in hygiene articles capable of absorbing body fluids such as urine, or in the packaging sector, e.g. meat and fish products, where they absorb large amounts of aqueous liquids and body fluids such as urine, blood, or meat juice, with swelling and formation of hydrogels. Therefore, the present invention is also directed to these uses.

The polymer products of the invention are incorporated directly as powders in constructions for absorbing liquids, or previously fixed in foamed or non-foamed sheet materials. For example, such constructions for absorbing liquids are diapers for babies, incontinence articles or absorbent inserts in packaging units for foodstuffs. In the absorbent polymer product according to the invention, binding of the zeolite to the polymer obviously is so strong that even under

mechanical stress, e.g. when conveying the absorbent polymer product, substantial separation and demixing of the polymer and zeolite cannot be observed and thus, in particular, problems of handling exceedingly fine particles do not occur.

Further processing of the polymer product according to the invention is advantageous because, according to prior art, separate and uniform dosage of superabsorber and zeolite, particularly with small amounts of zeolite, cannot be achieved. The polymer product according to the invention, which allows easy dosing, ensures a constant concentration of polymer product with superabsorbent properties and deodorant component in absorbent articles such as liners.

Moreover, the absorbents of the invention were found to be excellently suited for incorporating active substances. The stability of sensitive active substances, e.g. with respect to oxidative degradation, is substantially improved as a result of incorporation in the absorbents of the invention.

Furthermore, the polymer products according to the invention find use in plant breeding and in pest control in agriculture. In plant breeding, the polymer products in the vicinity of plant roots provide for sufficient supply of liquid and previously incorporated nutrients and are capable of storing and releasing same over a prolonged period of time.

In pest control, the polymer product can incorporate single active substances or a combination of multiple active substances which in use are released in a controlled fashion in terms of time and amount.

The invention will be illustrated in the following Examples. These illustrations merely are given by way of example and do not limit the general idea of the invention.

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Production and properties of the polymer products according to the invention will be explained. Furthermore, the test methods and procedures used to determine the characteristics of the polymers with superabsorbent properties will be described.

#### Test methods

**Test method 1:** The retention is determined according to the tea bag method and is given as mean value of three measurements. About 200 mg of polymer product is welded in a tea bag and immersed in a 0.9% NaCl solution for 30 minutes. The tea bag is subsequently centrifuged in a centrifuge (23 cm in diameter, 1400 rpm) for 3 minutes and weighed. A tea bag having no water-absorbing polymer is run as a blank.

$$\text{Retention} = \frac{\text{Final weight} - \text{Blank}}{\text{Initial weight}} \quad [\text{g/g}]$$

**Test method 2:** Liquid absorption under pressure (AAP test, EP 0,339,461)

The absorption under pressure (pressure load 50 g/cm<sup>2</sup>) is determined according to the method described in EP 0,339,461, page 7. This document is hereby incorporated by reference and thus represents part of the disclosure. About 0.9 g of superabsorber is weighed in a cylinder having a screen bottom. The uniformly spread superabsorber layer is loaded with a piston exerting a pressure of 50 g/cm<sup>2</sup>. The previously weighed cylinder then is placed on a glass filter plate situated in a tray containing a 0.9% NaCl solution, the liquid level of which precisely corresponds to the height of the filter plate. After allowing the cylinder unit to absorb 0.9% NaCl solution for 1 hour, it is reweighed, and the AAP is calculated as follows:

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**AAP** = Final weight (cylinder unit + superabsorber) - Initial weight (cylinder unit + soaked superabsorber) / Initial weight of superabsorber

**Test method 3:** Determination of the absorption of malodorous compounds

0.1 g of powdered absorbent is added with 2 ml of an aqueous solution (including 5 wt.-% ethanol) of malodorous compound, and this is sealed in a 5 ml test vessel. This is allowed to stand at 23°C for 12 hours, and the content of malodorous compound in the vapor space above the liquid is determined quantitatively against a blank using headspace GC.

**Test method 4:** The silicon content of the absorbent polymers is determined by reacting silicate to form molybdenum blue and subsequent photometric analysis. Previously, the silicon has been reacted quantitatively to form silicate, using alkaline decomposition (Photometrische Analyse, Authors: B. Lange, Zdenek, J. Vejdelek, S., edition of 1987, p. 383, VCH).

**Examples:**

**Example 1a**

This Example illustrates the production of a polymer gel having superabsorbent properties.

A solution of 1300 g of acrylic acid, 2115.9 g of distilled water, 2.7 g of polyethylene glycol monoallyl ether acrylate, and 1.25 g of polyethylene glycol diacrylate is prepared. Using 899.10 g of 50% sodium hydroxide solution, partial neutralization (degree of neutralization (DN): 60%) is effected with stirring and cooling. The solution is cooled to 7-8°C and purged with nitrogen for about 20 minutes.

Thereafter, 0.45 g of azobis(2-amidinopropane) dihydrochloride dissolved in 22.5 g of distilled Water, 1.35 g of sodium peroxodisulfate, dissolved in 25 g of distilled water, and 0.315 g of hydrogen peroxide (35%), dissolved in 22.5 g of distilled water, are added. Subsequently, the polymerization is initiated by adding 0.0675 g of ascorbic acid dissolved in 9 g of water, whereupon a significant rise in temperature occurs. A gel-like product is obtained, the further processing of which will be described in the following Examples.

#### Example 1b

This Example illustrates the production of another polymer gel having superabsorbent properties.

A solution of 1300 g of acrylic acid, 2015.9 g of distilled water, 6.5 g of polyethylene glycol monoallyl ether acrylate, and 3.9 g of polyethylene glycol diacrylate is prepared. Using 997.10 g of 50% sodium hydroxide solution, partial neutralization (DN = 70%) is effected with stirring and cooling. The solution is cooled to 7-8°C and purged with nitrogen for about 20 minutes. Thereafter, 0.45 g of azobis(2-amidinopropane) dihydrochloride dissolved in 22.5 g of distilled Water, 1.35 g of sodium peroxodisulfate, dissolved in 25 g of distilled water, and 0.315 g of hydrogen peroxide (35%), dissolved in 22.5 g of distilled water, are added. Subsequently, the polymerization is initiated by adding 0.0675 g of ascorbic acid dissolved in 9 g of water, whereupon a significant rise in temperature occurs. A gel-like product is obtained, the further processing of which will be described in the following Examples.

#### Example 1c

This Example illustrates the production of another polymer gel having superabsorbent properties.

A solution of 1300 g of acrylic acid, 2017.19 g of distilled water, and 3.9 g of triallylamine as crosslinker is prepared. Using 997.10 g of 50% sodium hydroxide solution, partial neutralization (DN = 70%) is effected with stirring and cooling. The solution is cooled to 7-8°C and purged with nitrogen for about 20 minutes. Thereafter, 0.45 g of azo-bis(2-amidinopropane) dihydrochloride dissolved in 22.5 g of distilled water, 1.35 g of sodium peroxodisulfate, dissolved in 25 g of distilled water, and 0.315 g of hydrogen peroxide (35%), dissolved in 22.5 g of distilled water, are added. Subsequently, the polymerization is initiated by adding 0.0675 g of ascorbic acid dissolved in 9 g of water, whereupon a significant rise in temperature occurs. A gel-like product is obtained, the further processing of which will be described in the following Examples.

#### Example 2

500 g of the gels obtained in Examples 1b-c are wil-lowed and sprayed uniformly with a suspension of Flavith® S108 (Degussa AG,  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio about 500) or Flavith® D (Degussa AG,  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio about 56) or zeolite A ( $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio <5) in water in amounts as specified in the following Table, and subsequently dried to a residual water content of <10% at 150°C in a circulating air oven. Examples e and f are Comparative Examples because the zeolite A that is employed is not a zeolite high in silicon.

Example	Retention [g/g]	Flavith S108 wt.-%	Flavith D wt.-%	Zeolite A wt.-%
2a	32.5*	1	0	0
2b	32.5*	2	0	0
2c	33.0*	0	1	0
2d	33.0*	0	2	0
2e*	31.0#	0	0	1
2f**	30.8#	0	0	2

\* Hydrogel obtained from Comparative Example 1b

# Hydrogel obtained from Comparative Example 1c

\*\* Comparative Examples

### Example 3

In this Example, the retention and liquid absorption under pressure of a polymer product having superabsorbent properties are examined in the absence of zeolite.

50 g of the dried and milled polymer from Examples 1a-c screened to 150-850  $\mu\text{m}$  is wetted with a solution of 0.5 g of ethylene carbonate and 1.5 g of water in a plastic vessel with vigorous stirring and mixed thoroughly using a commercially available household hand mixer (Krups company). Subsequently, the wetted polymer is heated in an oven at a temperature of 180°C for 30 minutes.

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Example	Retention [g/g]	AAP [g/g]
3a	32.0	22.5
3b	28.0	24.5
3c	27.0	23.5

**Example 4**

In this Example, surface crosslinking is effected subsequent to adding zeolite.

50 g of each dried and milled polymer from Examples 2a-f screened to 150-850  $\mu\text{m}$  is wetted separately with a solution of ethylene carbonate (EC) and water in a plastic vessel with vigorous stirring and mixed thoroughly using a commercially available household hand mixer (Krups company). The solution contains 0.25 g of EC per 1.8 g of water. Subsequently, the wetted polymer is heated in an oven at a temperature of 170°C for 30 minutes.

Example	Retention [g/g]	AAP [g/g]
4a	27.5	24.5
4b	27.5	24.5
4c	28.0	24.0
4d	27.5	24.0
4e**	27	23.5
4f**	26.5	23.5

## \*\* Comparative Example

**Example 5**

In this Example, the zeolite is added during surface crosslinking.

50 g of willowed, dried and milled polymer from Example 1a screened to 150-850  $\mu\text{m}$  is wetted in a plastic vessel with a solution of 0.25 g of ethylene carbonate and 1.8 g of water and a suspension of Flavith® S108 (Degussa AG) in amounts as specified in the following Table (given in % dry substance relative to acrylic acid) with vigorous stirring and mixed thoroughly using a commercially available household hand mixer (Krups company). Subsequently, the wetted polymer is heated in an oven at a temperature of 180°C for 30 minutes.

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Example	Retention [g/g]	AAP [g/g]	Flavith S108 wt.-%
5a	30.6	22.5	1
5b	29.7	21.8	2

As is clearly recognized, the retention or liquid absorption under pressure, as compared to Example 3, has changed only slightly within the scope of the measuring precision.

**Comparative Example 3a (analogous to WO 91/12029)**

10 g of methylcellulose (Walocel VP-M 20678) is dispersed with 40 g of Flavith® S108 and 190 g of water using a high speed mixer, subsequently mixed with 50 g of a commercially available superabsorber (Favor® SXM 6860 by the Stockhausen company) in a laboratory mixer, and dried in a fluid-bed dryer at 60°C in a constant air flow for 20 minutes.

**Comparative Example 3b (analogous to WO 91/12029)**

0.25 g of methylcellulose (Walocel VP-M 20678) is dispersed with 1 g of Flavith® S108 and 5 g of water using a high speed mixer, subsequently mixed with 50 g of a commercially available superabsorber (Favor® SXM 6860 by the Stockhausen company) in a laboratory mixer, and dried in a fluid-bed dryer at 60°C in a constant air flow for 20 minutes.

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Designation	TB [g/g]	AAP [g/g]
C3a	20.5	9.0
C3b	29.0	18.4
SXM 6860	31.0	24.0

In addition to a dramatically deteriorated performance, particularly in the absorptive capacity under pressure compared to SXM 6860, the instability of the composite material can already be seen in a heavy formation of dust when mixing or conveying the material.

#### Comparative Example 4

In this example, the zeolite is added subsequent to surface crosslinking.

50 g of the product obtained in Example 4 is sprayed with thorough mixing with a suspension of zeolite (Flavith® S108, Degussa-Hüls company) in water in the amounts specified in the following Table. The product is dried to a residual water content of <4% in a drying oven.

Designation	Flavith S108 [%]
C4a	2
C4b	1

**Example 6**

The product obtained in Comparative Examples 3 and 4 is screened, and the fraction having a grain size of 150-850  $\mu\text{m}$  is subjected to a ball mill stability test wherein the product is stressed for 6 minutes at 95 rpm in the ball mill. Likewise, the product obtained in Example 2b is subjected to the same ball mill stability test. Again, the products are screened, and the fraction having a grain size of <150  $\mu\text{m}$  is examined for its silicon content using test method 4. As the zeolite that is employed has a grain size markedly below 150  $\mu\text{m}$ , this method allows a determination of the amount of zeolite that has been bound to or incorporated in the polymer having superabsorbent properties. The following quantities of silicon, relative to total dry substance, are found in the samples:

Product from Example	Ball mill test	SiO <sub>2</sub> content [%]	Theoretical SiO <sub>2</sub> content* [%]
Comp.Ex. according to Example 1 of WO 91/12031**	Yes	5.2	2
Comp.Ex. C3a	No	79.9	40
Comp.Ex. C3a	Yes	79.1	40
Comp.Ex. C3b	No	5.3	2
Comp.Ex. C3b	Yes	3.2	2
2b	Yes	1.7	2
Comp.Ex. C4a	Yes	2.9	2

\* Relative to the total amount of polymer of the invention having superabsorbent properties.

\*\* 50 g of SAP (Superabsorber by Stockhausen company; FAVOR® SXM 6860) and 1 g of Flavith® S108 have been mixed using a Krups company kitchen mixer. After adding 15 g of water, aggregation of the material is observed. Drying at 60°C for 120 minutes.

As is clearly recognized, the products of the invention in the fraction of particles <150 µm have significantly less silicon compared to products produced according to prior art, providing evidence that binding of the zeolites to the polymer is significantly stronger in the products according to the invention. Similarly, the composite materials produced following WO 91/12029 and WO 91/12031 are significantly more unstable compared to the products of the invention, as evidenced by the increased SiO<sub>2</sub> content in the fine dust

prior to and subsequent to the ball mill stability test. In particular, it is apparent that prior art processes are not capable of effectively binding such high amounts of zeolite because a high percentage of the hydrophobic zeolite still is separated from the superabsorber material after production. When subjecting the material to mechanical stress, large amounts of zeolite are removed additionally, as characterized by the high silicon dioxide content in the fine dust after stressing in the ball mill. Comparative Example C4a demonstrates that, even when using small amounts of zeolite (2%), binding in prior art processes is significantly poorer compared to the process according to the invention (Ex. 2b).

#### Example 7

This Example examines the reduction in the vapor space concentration of malodorous compounds.

In the measurement of malodorous substances, a polymer with no zeolite is examined as a blank according to test procedure 2, and the vapor space concentration of malodorous substance found is set as 100%. Subsequently, samples containing zeolite are examined, and the vapor space concentration of malodorous substance is determined. The figures in the right column are calculated as follows:  $100 \times (\text{detected amount of odorous substance from polymer containing zeolite} / \text{detected amount of odorous substance from polymer free of zeolite})$ .

**Doping with furfurylmercaptane and ethylfuran:**

Polymer from Example	Reduction of furfurylmercaptane concentration in the vapor space [%]	Reduction of ethylfuran concentration in the vapor space [%]
4a	69.0	82.0
4b	89.0	93.0
4c	40	-
4d	66	-
4e	Reduction < 5%	Reduction < 5%
4f	Reduction < 5%	Reduction < 5%
5g	91.9	-
5h	99.1	-

- not measured

The absorbent polymer products of the invention exhibit a significant reduction of malodorous substances.

As shown by the Comparative Examples, zeolites having a low silicon dioxide/aluminum oxide ratio do not result in a satisfactory reduction in the vapor space concentration of malodorous substances.

In order to have an additional confirmation, a commercially available FAVOR® superabsorber by Stockhausen company is mixed intimately with 2 wt.-% of various hydrophilic zeolites (A, P, X) having an  $\text{SiO}_2/\text{Al}_2\text{O}_3$  ratio of <5, and the reduction of odorous substances is examined.

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Compared to a sample with no zeolite, no reduction of the concentration of odorous substances in the vapor space above the sample is found.

## Claims:

1. An absorbent, crosslinked polymer for water or aqueous body fluids, based on optionally partially neutralized, monoethylenically unsaturated monomers bearing acid groups, characterized in that the polymer has zeolites high in silicon at least partially bound ionically thereto or incorporated therein.
2. The polymer according to claim 1, characterized in that the polymer includes and at least 0.01-10 wt.-%, preferably 0.1-5 wt.-%, and more preferably 0.7-3 wt.-% of zeolites high in silicon.
3. The polymer according to claim 1 or 2, characterized in that the zeolite high in silicon has a silicon dioxide/aluminum oxide ratio in its skeleton of >20, preferably >50, more preferably >100, with >500 being particularly preferred.
4. The polymer according to any of claims 1 to 3, characterized in that the polymer is constituted up to 30% of further monoethylenically unsaturated monomers other than the monomers bearing acid groups.
5. The polymer according to any of claims 1 to 4, characterized in that the polymer has 40 wt.-% of a water-soluble, natural or synthetic polymer incorporated therein by polymerization and/or graft polymerization.
6. The polymer according to any of claims 1 to 5, characterized in that the polymer has been coated with 0.01-30 wt.-%, preferably 0.1-10 wt.-%, relative to the polymer, of a crosslinker component which reacts with at

least two carboxylic groups in the surface layer of the polymer particles, thereby effecting crosslinking.

7. A process for producing the polymers according to any of claims 1 to 6 by free-radical polymerization of an aqueous solution of ethylenically unsaturated, optionally partially neutralized monomers bearing acid groups, optionally up to 30 wt.-% of further monoethylenically unsaturated comonomers, crosslinking monomers, and optionally up to 40 wt.-% of a water-soluble natural or synthetic polymer according to the process of solution or suspension polymerization to form a hydrogel, optional isolation, crushing, followed by drying, milling/screening, and secondary surface crosslinking, characterized in that the zeolite high in silicon is added to the polymer during its surface crosslinking at the latest, preferably in suspension.
8. A process for producing the polymers according to any of claims 1 to 7 by free-radical polymerization of an aqueous solution of ethylenically unsaturated, optionally partially neutralized monomers bearing acid groups, optionally up to 30 wt.-% of further monoethylenically unsaturated comonomers, crosslinking monomers, and optionally up to 40 wt.-% of a water-soluble natural or synthetic polymer according to the process of solution or suspension polymerization to form a hydrogel, optional isolation, crushing, followed by drying, milling/screening, characterized in that the zeolite high in silicon is added to the polymer at a water content of >10 wt.-%, preferably in suspension.
9. The process according to claim 8, characterized in that the water content is >30, preferably >50, and more preferably >65 wt.-%.

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10. Use of the polymers according to any of claims 1 to 6 for improved absorption of odors from body fluids.
11. Use of the polymers according to any of claims 1 to 6 as an absorbent for aqueous liquids, preferably in constructions for absorbing body fluids, in foamed and non-foamed sheet materials, in packaging materials, in plant breeding, and as soil improver.
12. Use of the polymers according to any of claims 1 to 6 in hygiene articles.
13. Use of the polymers according to any of claims 1 to 6 as a vehicle and/or stabilizer for active substances, particularly fertilizers or other active substances being released optionally in a delayed fashion.

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